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Efficient non-deterministic analysis of PA-12 components, produced via Laser Sintering

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Additive Manufacturing (AM) techniques are becoming increasingly popular for the production of functional components. In the context of producing plastic parts for end-use applications, Laser Sintering of PA-12 is deemed to be one of the most promising AM processes, as it offers a good compromise between dimensional accuracy and mechanical performance [1]. However, despite the maturity and wide application of the Laser Sintering process, produced parts still present a large variability in their elastostatic properties. This variability is caused by complex interactions between both the process parameters (e.g., scan speed, path orientation), process state variables during the process (e.g., local temperature), material parameters (e.g., melt viscosity and -enthalphy) and the process planning prior to production (e.g., placement of parts in the envelope). This variability manifests itself both in low-level material properties such as porosity [2] and crystallinity [7], leading also to a non-trivial amount of variability in high-level properties such as Young's modulus and yield strenght, sometimes up to 7% of the nominal value in a single batch [4]. Moreover, recent work by the authors has also indicated that intra-variability is present on Young's modulus of PA-12 parts produced via Laser Sintering, caused by differences in scanned cross-sectional area between subsequent layers [4]. Therefore, in order to obtain a reliable and robustly designed functional component the inherent variability that is present in the elastostatic properties of PA-12, produced via Laser Sintering, has to be taken into account already during the design process.

This paper first therefore presents an overview of the variability in the elastostatic properties of Laser Sintered PA-12 parts based on mechanical tests, performed on a test population with a statistically relevant size. This test population includes the effects of building orientation and location in the build platform, two parameters that have been shown to influence the elastostatic properties to a large extent [5]. Based on this dataset, two non-deterministic constitutive models are constructed: a homogeneous probabilistic isotropic model and a heterogeneous interval field isotropic model (see e.g., [3] or [8] for an explanation of the concept of interval fields). As such, both probabilistic and possibilistic techniques are considered for the representation of the non-determinism that is present in the elastostatic properties of PA12 parts, produced via Laser Sintering. These non-deterministic material models are subsequently used to model the non-deterministic elastostatic response a well-defined benchmark specimen (which is shown in figure 1), and the results of both models are critically compared in terms of computational cost and predicted variability. Hereto, a Finite Element model is constructed to simulate a predefined loading situation of the benchmark specimen, and the non-determinism in the constitutive model is propagated through this model. Specifically, the probabilistic model response (in terms of probability density functions of the stress and strain responses) is approximated using Monte Carlo sampling, whereas the interval field model is solved for the respective uncertain realisation sets using the Transformation Method [6]. Finally, also a set of 12 replica of this benchmark specimen are produced using Laser Sintering in PA-12, and the mechanical response is measured using Digital Image Correlation (DIC) in order to asses the real-world accuracy of both non-deterministic material models. Figure 1 shows the measured strain fields in this benchmark sample at a load of 1500N.

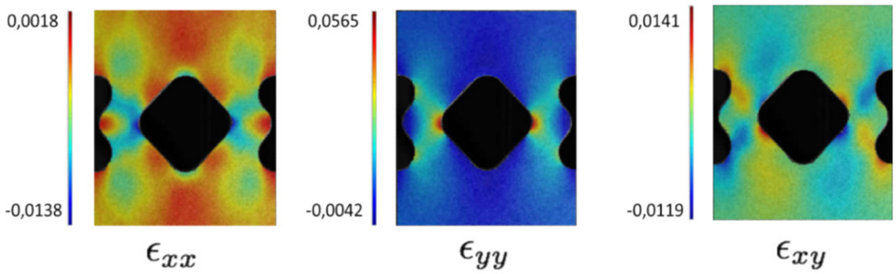

Figure 1: Longitudinal (ϵ_{yy}), transversal (ϵ_{xx}) and shear (ϵ_{xy}) strain fields in the loaded benchmark component (taken from previous work of the authors in [4]).

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